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POLE BLIGHT INVESTIGATIONS BY FOREST PATHOLOGY, 1948

Introduction

In November 1947, Wellner[1/] summarized the pertinent information

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1/Wellner, C. A. Pole Blight--a new disease of western white pine. Station Paper No. 8, Northern Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, Missoula, Montana. 5 pp. Mimeographed. Illus. Nov. 1947.

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then available on a serious disease of western white pine called pole blight. The disease is responsible for heavy mortality in pole-sized stands ranging in age from 40 to 100 years and has caused concern to foresters and timber owners for over a decade. Losses on the Coeur d'Alene and Kaniksu National Forests have been particularly severe and are continuing with no sign of abatement. Furthermore, there are strong indications that the disease is spreading to new localities throughout the commercial range of western white pine. It has not yet been found in the Clearwater drainage.

Heretofore the Division of Forest Pathology (B.P.I.S. & A. E.) has given only casual attention to pole blight. Pathological investigations have, for the most part, been conducted by staff members of the School of Forestry of the University of Idaho in connection with the U. S.

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Forest Service. The early University of Idaho work is summarized in several publications and reports[2/] which, however, do not reveal the cause or causes of the disease.

2/ (1) Ehrlich, John. A preliminary study of root disease in the western white pine type. Office report Northern Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, Missoula, Montana. June 20, 1939. (Copy also on file at the School of Forestry, University of Idaho, Moscow, Idaho.)

(2) Ehrlich, John. A preliminary study of root diseases in western white pine. Station Paper No. 1, Northern Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, Missoula, Montana. 10 pp. Mimeographed (Illus.) October 1939.

(3) Ehrlich, John and Loren K. Baker. Preliminary study of dying young white pine on Coeur d'Alene and Kaniksu Forests. Report on an administrative protection study of the Forest Service Regional Office (R-1) with the cooperation of the University of Idaho. 50 pp. and 14 tables typed June 1942.

(4) Welch, D. S. Study of the mortality of young western white pine trees. Report for 1947. Special Research Project No. 11. School of Forestry, University of Idaho. Dec. (?) 1947.

Early in 1948 it was suggested by the Forest Service and the North Idaho Forestry Association that the Division take an active part in pole

blight research. By mid-May a field party was at work in Idaho and operations were continued in the white pine type until October. Figure 1 attempts to give a picture of the geographical extent of this work. The purpose of this report is to describe the Division's activities and current results.

The project was under the general supervision of Lee M. Hutchins, Head Pathologist in Charge, Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, Beltsville, Maryland. Those assigned directly to the problem were L. S. Gill, Senior Pathologist, in charge of party, S. R. Andrews, Associate Pathologist, and R. E. Millenbaugh, Scientific Aid, all detailed from the Division's branch station at Albuquerque, New Mexico. During the last half of July, Bratislav Zak, from the Division's branch station at Athens, Georgia, assisted in developing grafting techniques adaptable to virus disease tests. In August (Aug. 16-18, inc.) F. P. Cullinan, Assistant Chief, B.P.I.S. & A. E., Beltsville, Maryland, inspected the work and made numerous helpful suggestions.

An excellent opportunity to become thoroughly acquainted with the background of the disease was afforded by a meeting June 1 and 2 at the Deception Creek Experimental Forest. Details of this meeting were outlined by Dr. T. S. Buchanan of the School of Forestry, University of Idaho in his circular letter of July 10, 1948; they were also reviewed

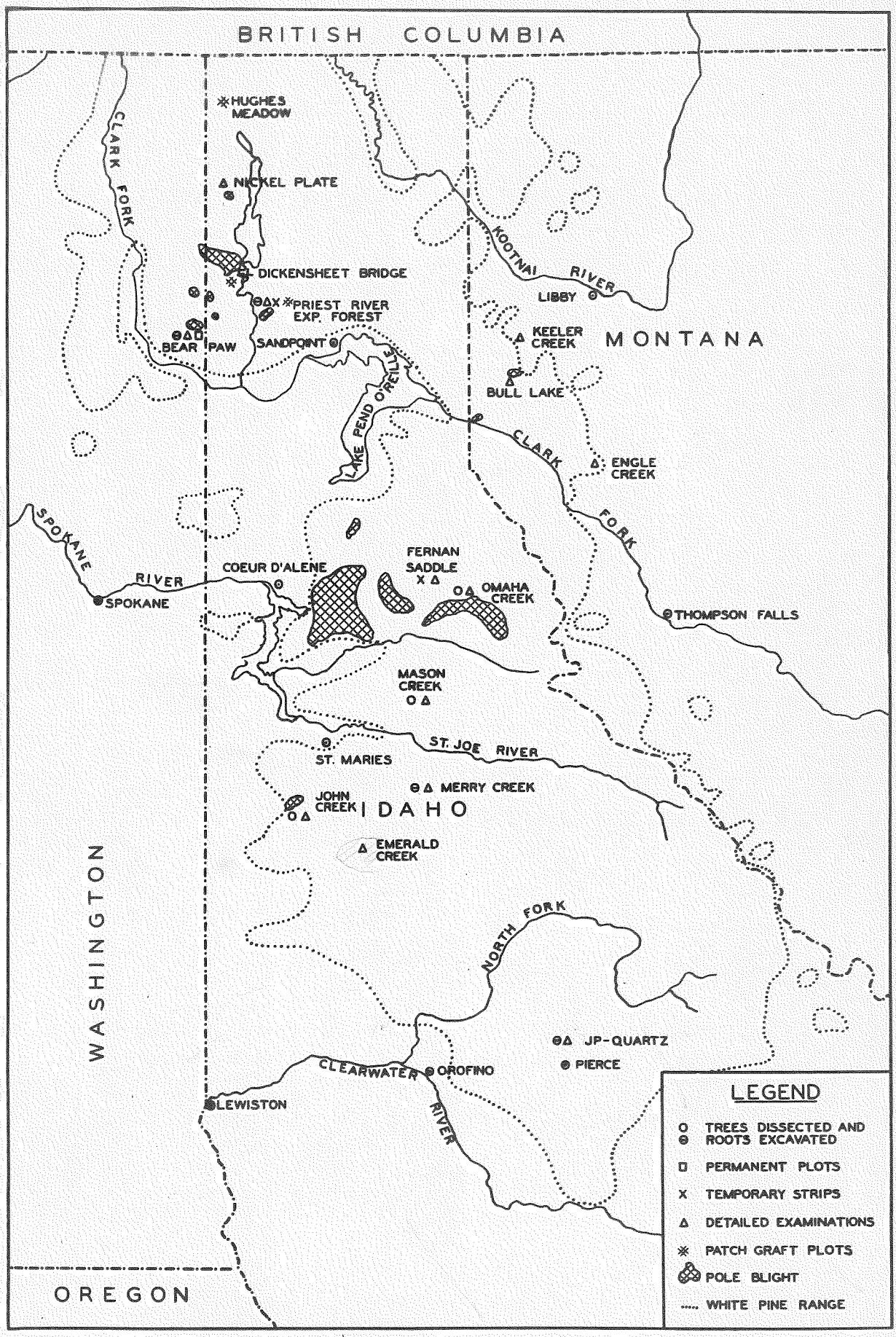

Figure 1.--Map of the Inland Empire showing the range of western white pine, the location of recognized pole blight areas, and the locations of pathological studies.

in his recent publication.3/ At the meeting, Dr. Hutchins expressed

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3/Buchanan, Thomas S. Study of mortality of young western white pine trees. University of Idaho Bulletin Vol. XLIII, No. 6, pp. 28-33. Illus. Dec. 1948. (Fifth Progress Report of the Special Research Program of the University of Idaho.)

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the Division's interest in the problem and indicated the practical importance of determining as quickly as possible whether or not pole blight is infectious. Our principal efforts were accordingly directed toward that end. Satisfactory control obviously will hinge on the answer to that question.

Following the Deception Creek meeting a conference was held at the School of Forestry, University of Idaho, at which Dean Dwight S. Jeffers and Dr. Hutchins agreed upon a joint plan for conducting the pathological investigations for the current season.

Activities

While a detailed account of our field activities is contained in the monthly progress report issued by Dr. Buchanan and circulated to persons interested in pole blight they are of necessity repeated in briefer form here. In addition, this report includes some information that has developed since our field work was closed out and contributions to the monthly report ceased.

General surveys

Thanks to the assistance of Mr. C. A. Wellner of the Northern Rocky Mountain Forest and Range Experiment Station, we were able to obtain a general picture of the disease and its distribution with the least possible loss of effort and time. This included (1) visits to most of the areas used by Ehrlich and Baker (See Footnote 2, Reference 3) for their studies, (2) inspection of other areas now severely blighted which Wellner recalled as having been apparently healthy in 1941, and (3) inspection of pole stands suffering from prolonged bark beetle attack on the Coeur d'Alene National Forest.

In addition, during the course of the field season we made several examinations of stands both younger and older than those considered to be susceptible to pole blight. This at least inspired some speculation as to whether or not (1) there might be an age spread in many old stands that would suggest heavy losses in times past when the trees had previously reached pole-blight age and (2) whether or not mortality in young stands, especially plantations, might be due in part, at least, to the same factors responsible for pole blight.

Stem dissections

Since systematic tree dissection was a major project of the University of Idaho group both in 1947 and 1948 we did not undertake it on a large scale. Our work in this field was limited to a few scattered trees and was performed with three major purposes in mind, namely: (1) to become familiar with the

various manifestations of pole blight as they appeared in the stem, (2) to obtain material for isolating micro-organisms associated with the disease, and (3) to obtain material for histological study.

Two trees, one on lower Benton Creek and the other on Bear Paw Creek of the Kaniksu National Forest, were dissected in more detail than the others. Both were obviously pole-blighted to the best of our ability to evaluate symptoms at that time. Canker patterns of each are shown in Figures 2 and 3 and descriptive data are given in Table 1. In both cases necrosis of the stem appeared to be of considerably more recent origin than serious deterioration of the roots. Judging by height and diameter growth however, the Bear Paw tree suffered a much more rapid decline than did the one at Benton Creek. The Bear Paw area had been subjected to an improvement cutting in 1939 and there had been a weeding of poor trees or undesirable species at Benton Creek in the mid-1930's. No indication could be found of buried lesions indicative of cankers that had formed in earlier years and from which complete recovery had been made. However, the Benton Creek tree had several elongate cankers on which partial healing had occurred (Fig. 3 and Plate III top left and right). There was no suggestion of heal on the larger dead areas though the latter were obviously the result of progressive necrosis which had developed over a period of several years. In all of the trees which we examined the latter condition was much more common than the narrow partially healed cankers.

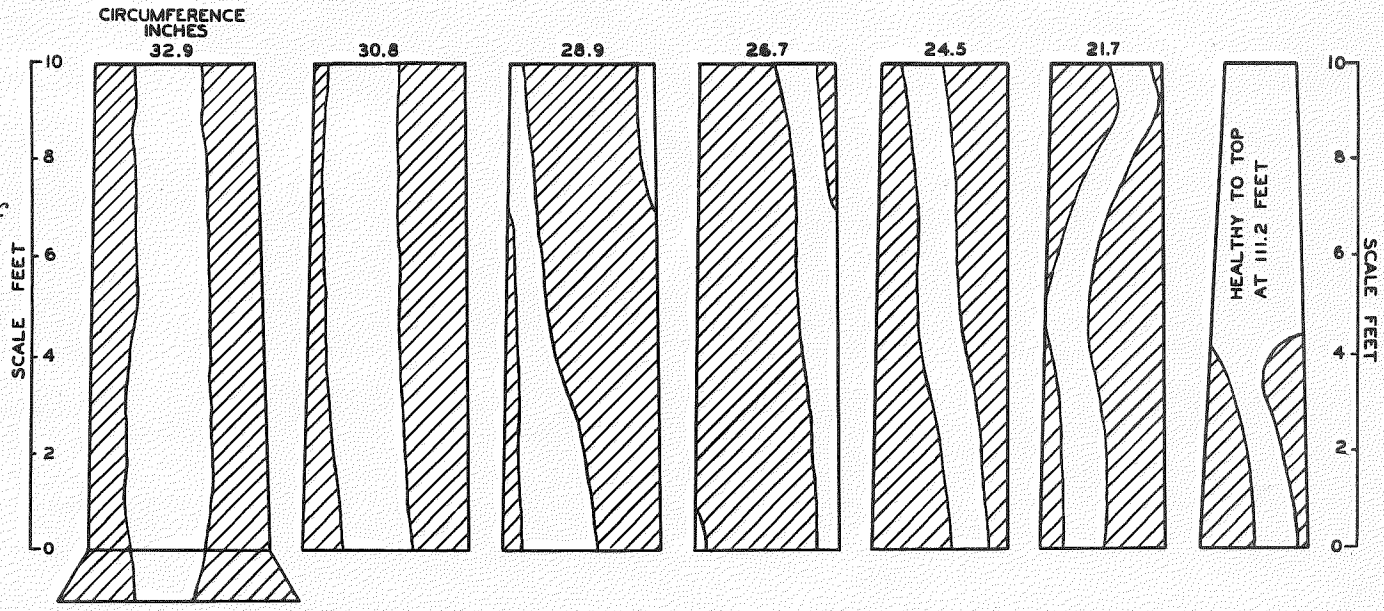

Figure 2.--Pattern of bark necrosis found in dissected tree from the Bear Paw tract (Kaniksu National Forest). Sections represent conditions found in 10 ft. lengths of peeled bark; hatched areas indicate dead bark.

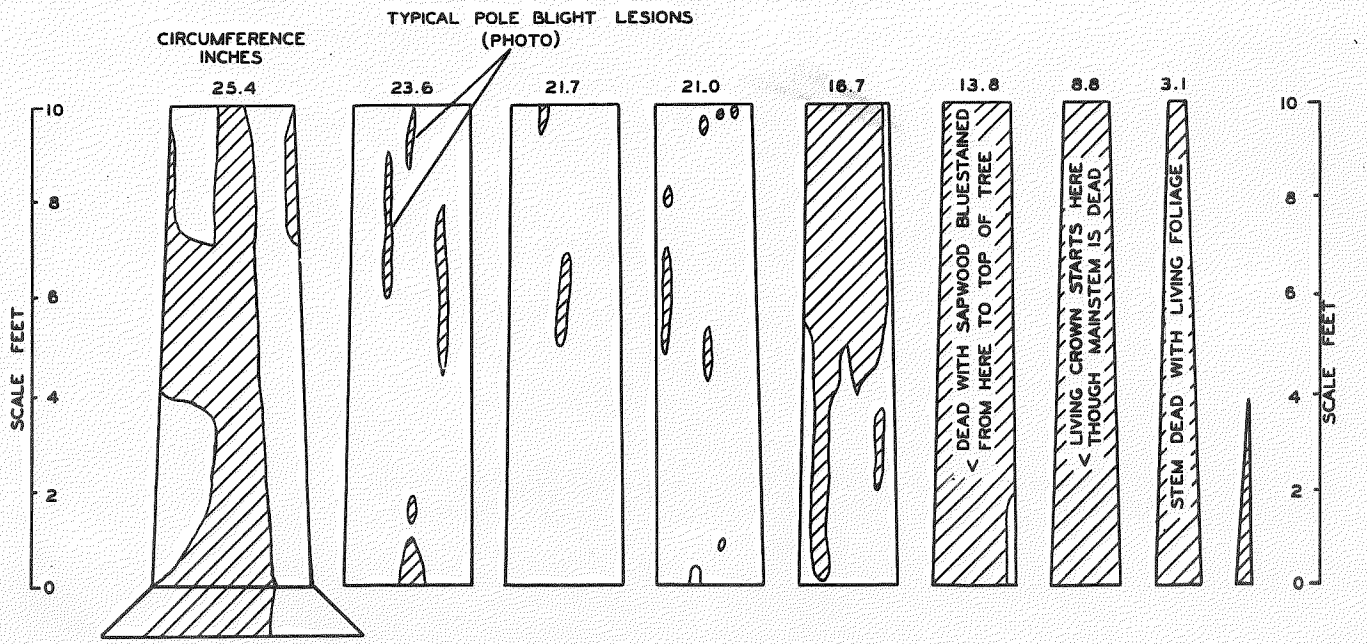

Figure 3.--Same as Figure 2 except dissected tree is from Benton Creek (Kaniksu National Forest). The elongated cankers marked "photo" at 16 - 20 feet above the stump are shown in Plate III top right and left. These cankers show an effort to heal which is not the case with the larger necrotic areas.

Table 1.--Descriptive data for trees shown in Figures 2 and 3

Observations	Benton Creek Tree (Fig. 3)	Bear Paw Tree (Fig. 2)
D.b.H. (inches)	8.6	11.0
Height (feet)	84.8	111.2
Age (years)	80+	70+
Crown class	Intermediate	Dominant
Average annual height growth 43-47	0.30 ft.	0.22 ft.
Average annual height growth 38-42	0.33 ft.	0.86[1/] ft.
Apparent degree of disease	heavy	heavy
Foliage	thin short yellowish	thin short yellowish
Resin flow	light	light
Cankers	obvious	obvious
Periods of poor growth at stump height;		
very poor	1913-1947	1942-1948
poor	1886-1893; 1908-1913	1936-1941
Condition of root collar	Diseased; with mycelial felts and resin flow present.	Diseased; with mycelial felts and resin flow present.
Condition of roots over 1 inch diameter at stump	over 1/2 dead or diseased.	Some dead and diseased.
Condition of minor roots	poor	fair
Tap root	poorly developed	poorly developed

1/Average based on 1940-42 only; all older growth more than 1.0 ft.

Root studies

Several approaches were tried in attempting to devise a satisfactory and efficient method of studying white pine root systems in relation to pole blight. This involved not only the mechanics of exposing the roots but also the measurements, observations, and collections which should be made from them.

Washing was attempted in the case of the Benton Creek tree described under Stem dissections. In the case of the Bear Paw tree the main laterals were cut about 18 to 24 inches from the root collar and the tree was pushed over in the manner described by Ehrlich and Baker in their 1941 studies. In the latter case several lateral roots were subsequently exposed by digging.

Following the experience gained from the two examples cited above a detailed study of root systems was undertaken at several widely scattered locations in the white pine range. These are listed in Table 2.

The root systems of trees 1 to 4 inclusive were washed with a water stream of approximately 100 lbs./in.^{2} until most of the lateral roots were exposed. The root system was then diagramed as shown in Figures 4 - 7 inclusive. Plate I (top) shows a root system exposed for diagraming. Two-foot square string quadrats were laid out on the ground to aid in making the drawings which include all lateral roots observed to perhaps a depth of 18 inches. Trees 5 to 8 inclusive were excavated to a similar extent without the use of water, and were not diagramed.

Table 2.--Location of trees used in root studies

Geographic Designation	No. Healthy Trees	No. Diseased Trees	Tree Ref. No. (Text)
Kaniksu National Forest Benton Creek	1	1	1-2
St. Joe National Forest Merry Creek	2	0	3-4
Clearwater Nat'l Forest J.P.-Quartz Drainage	2	0	5-6
Kaniksu National Forest Bear Paw Creek	1	1	7-8

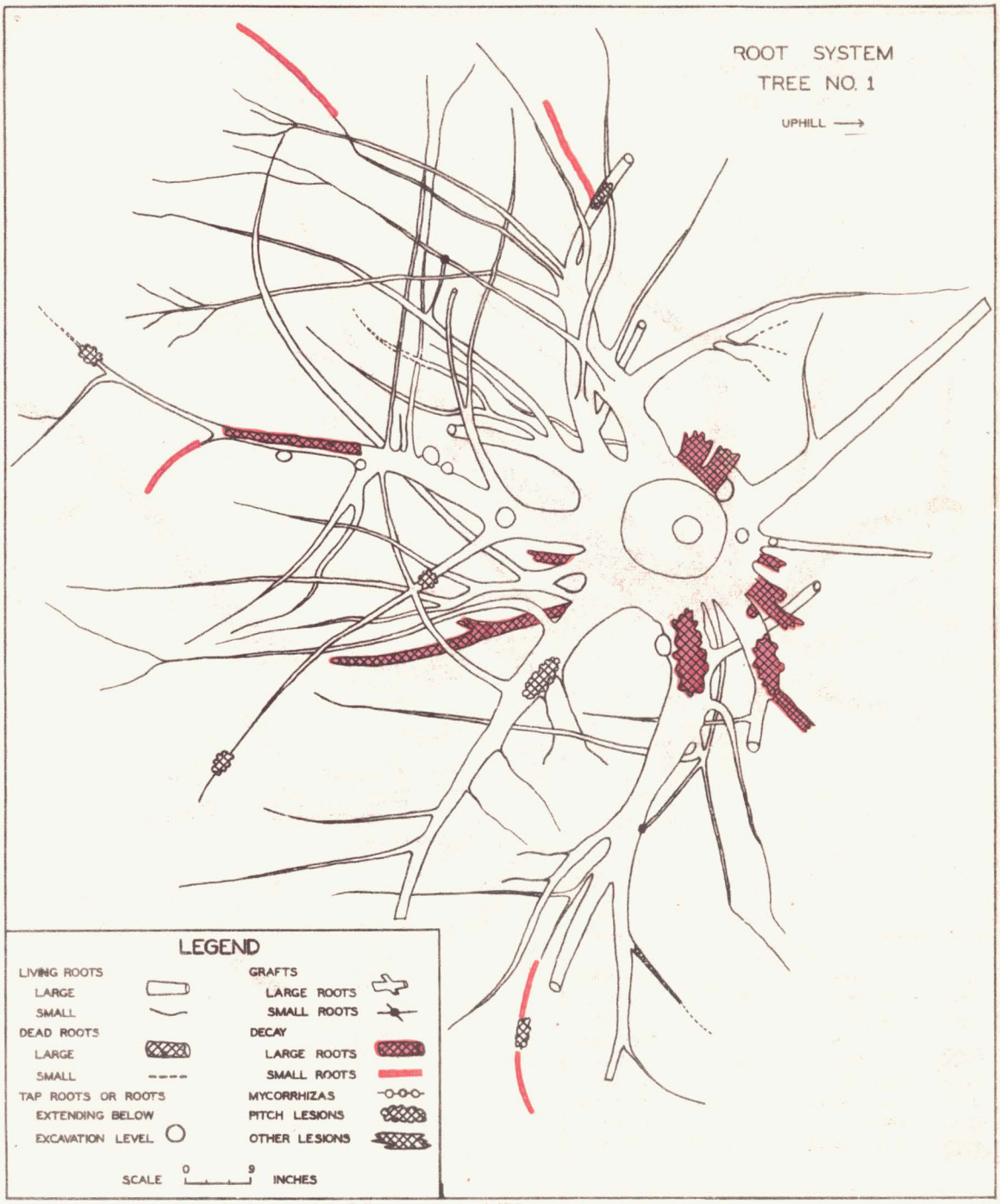

Figure 4.--Diagram of root system of an 80-year old dominant western white pine with a d.b.h. of 13.2 inches and a total height of 104 feet. The tree was classified healthy by the University of Idaho group that felled it and dissected the above-ground portion. The root system to a depth of 4 feet below ground level at the stump was then excavated and examined by Forest Pathology. Tree No. 41 (U. of I.), lower Benton Creek, Kaniksu National Forest.

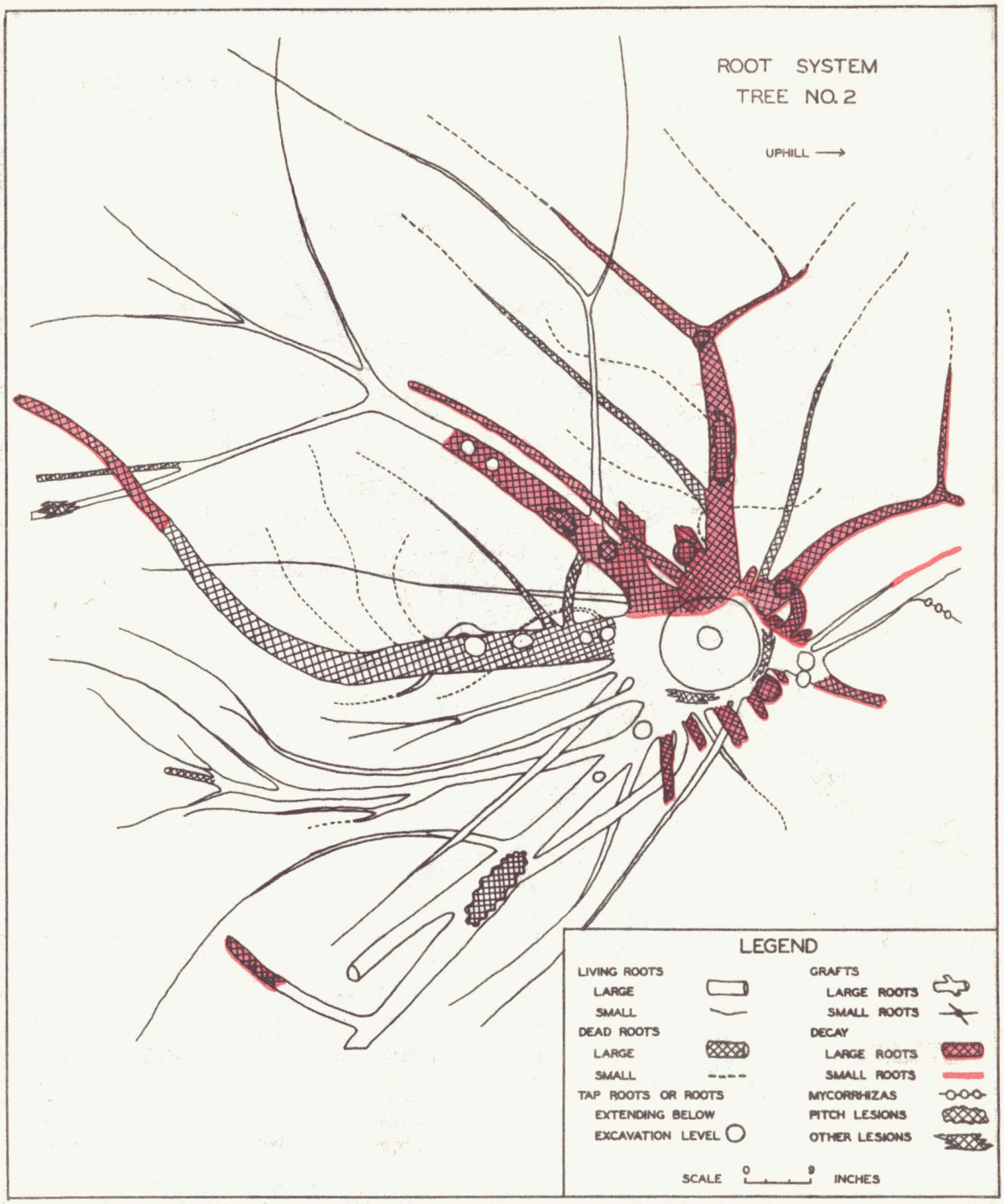

Figure 5.--Diagram of root system of a 70-year old dominant western white pine with a d.b.h. of 12.0 inches and a total height of 104 feet. The tree was classified early pole-blight by the University of Idaho group that felled it and dissected the above-ground portion. The root system to a depth of 4 feet below ground level at the stump was then excavated by Forest Pathology. Tree No. 42 (U. of I.), lower Benton Creek, Kaniksu National Forest.

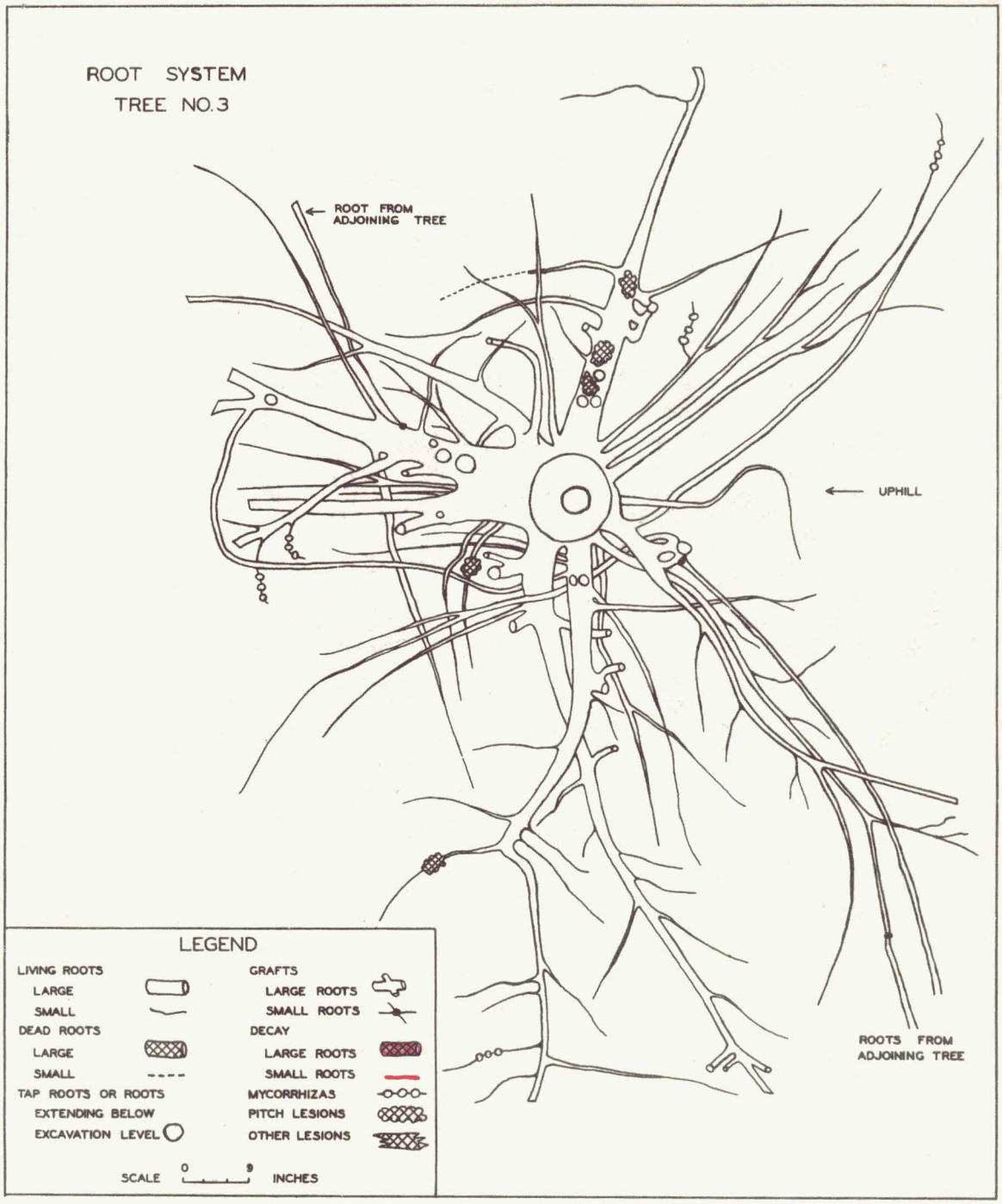

Figure 6.--Diagram of root system of 60-year old codominant western white pine with a d.b.h. of 10.0 inches and a height of 75 feet. The tree was classified healthy. Although it had moderate blister rust infections on branches, it did not show any symptoms of pole blight. The root system to a depth of 4 feet below ground level at the stump was excavated and examined. Tree No. 3 Merry Creek, St. Joe National Forest.

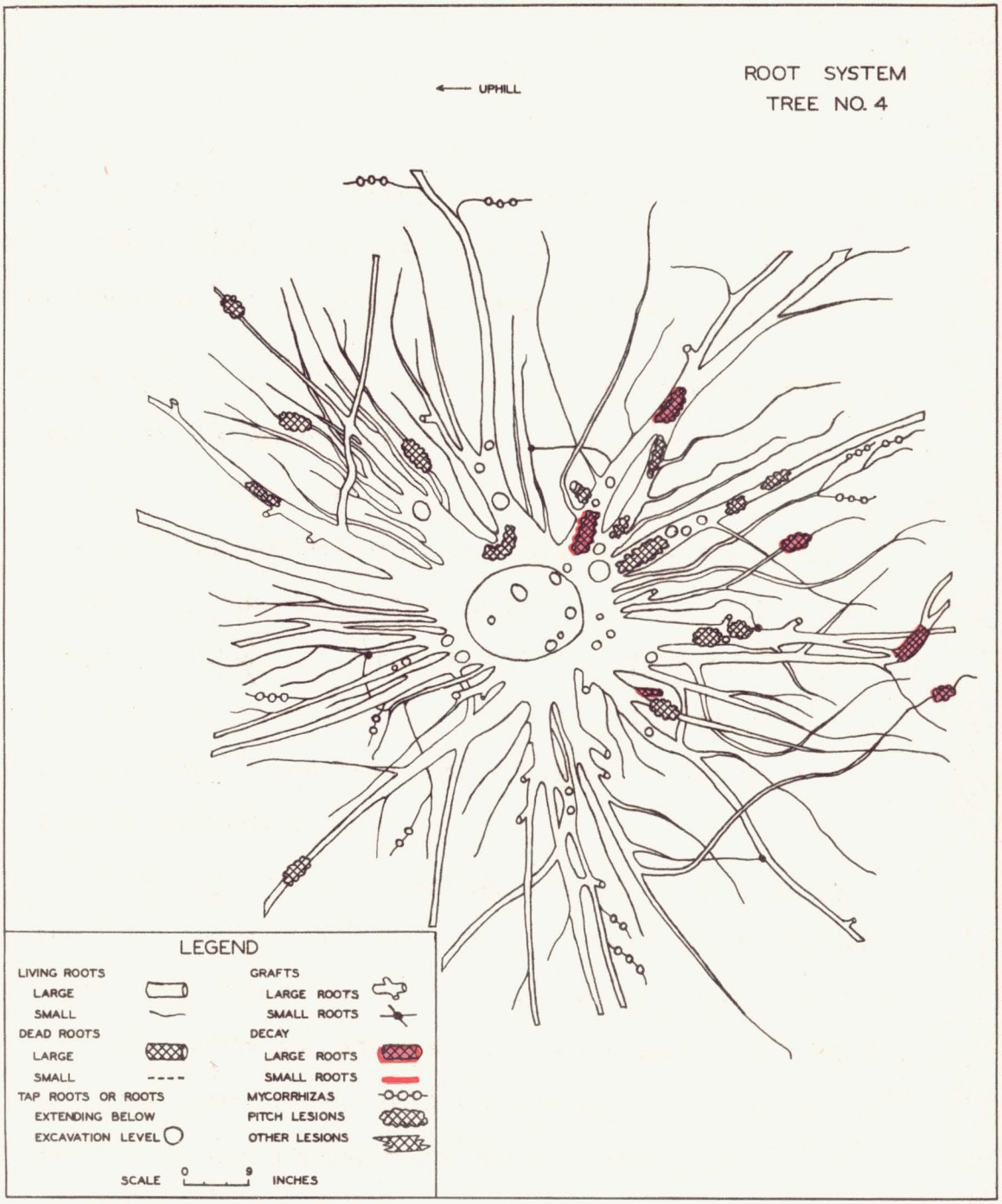

Figure 7.--Diagram of root system of 60-year old codominant western white pine with a d.b.h. of 12.8 inches and a height of 84 feet. The tree was classified healthy. Although it had light blister rust infection on branches, it did not show any symptoms of pole blight. The root system to a depth of 4 feet below ground level at the stump was excavated and examined. Tree No. 4 Merry Creek, St. Joe National Forest.

The stumps of all trees were cut or split longitudinally as shown in Plate I (bottom). In some cases the stump was dissected further. Pertinent observations relative to all trees are given in Table 3.

The impressions gained from the foregoing pilot study are:

(1) That a diseased condition in the root system is part of the pole blight complex.

(2) That the earliest symptoms of the disease are likely to appear in the roots. If such is the case it will not be surprising if killing occurs in the Merry Creek area of the St. Joe a few years hence. We are inclined to regard trees 3 and 4 (Figs. 6 and 7) as manifesting early symptoms of root deterioration.

(3) That the presence of Armillaria mellea, Fomes annosus, and other root-rotting fungi does not necessarily mean these organisms were primarily or in themselves responsible for the decline of trees exhibiting symptoms suggestive of pole blight.

(4) That layers of rock or heavy clay in the soil affect tap root development adversely and when such layers are close to the surface the tap root may be diverted from its downward path to become essentially a major lateral. What effect, if any, this may have on favoring pole blight is not clear. (Plate I, bottom)

Table 3.--Summary of observations of root systems after exposure by washing (Trees 1-4) and by digging (Trees 5-8)

Tree[1]				Condition[2] of				Buttress roots		Lateral roots[3]				
										Large		Small		
No.	D.b.h. (ins.)	Ht. (ft.)	Age (yrs.)	Stand	Tree[4]	Roots	Tap Root	No.	Dead or Decayed	Death or Decay[5]	Pitch Lesions[5]	Death or Decay[5]	Water soaked bark[5]	Mycorrhizas[5]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	13.2	104	78	D	H	D	Normal	3	1	M	C	M	-[6]	N
2	12.6	104	71	D	D	D	do.	4	3	H	C	H	-	R
3	10.0	75	56	H	H	H	do.	5	0	N	C	L	-	C
4	12.8	84	58	H	H	D[7]	do.	5	0	L	C	N	-	C
5	9.0	59	40	H	H	H	do.	4	0	N	R	N	N	A
6	16.6	114	70	H	H	D[8]	do.	4	0	N	R	N	N	A
7	15.0	108	71	D	D	D	Diverted	6	4	M	C	M	C	A
8	19.2	124	71	D	H	D	do.	5	0	L	R	L	C	A

1/Trees 1-2 lower Benton Creek, Kaniksu National Forest; trees 3-4 Merry Creek, St. Joe National Forest; trees 5-6 J.P.-Quartz Area, Clearwater National Forest; trees 7-8 Bear Paw Creek, Kaniksu National Forest.

2/Condition: H = healthy, D = diseased.

3/Large laterals = 3/4 in. and larger. Small laterals = 1/4 to 3/4 in.

4/Based on external above-ground appearance.

5/Symbols as follows: A = abundant, C = common, H = heavy, L = light, M = moderate, N = negligible, R = rare.

6/Not recorded.

7/Large laterals diseased. Small laterals apparently healthy.

8/Cut about 1 month before roots were excavated and some deterioration had set in.

Fungus Isolations

Table 4 summarizes the source of isolations made in connection with investigations of the cause of pole blight. As the table indicates, material was collected from the stems and roots of both healthy and blighted trees. Plates II and III illustrate some typical sources of isolates. In all but a few cases, the original isolations to petri dishes were made in the laboratory of the Priest River Experimental Forest. Because of limited storage space, transfers were made to test tubes as soon as fungi had become established. Isolations that became generally contaminated or that remained sterile for about 2 weeks were repeated at least once. Whenever obvious duplicates from different sources could be recognized, one was discarded in order to reduce the number of cultures requiring care.

Time and personnel were not available for simultaneous taxonomic studies even when the frequency of isolation elicited considerable interest in the relation of a particular organism to pole blight. For example, organism No. 603 (Scopularia sp.) and similar isolates were frequently cultured from lesioned bark and discolored wood of diseased roots from healthy and blighted trees. Inoculation tests summarized in this report suggest that Scopularia may be parasitic to some degree. Specific identification of the fungus will require still further study.

Of the fungi known to attack roots of western white pine, Armillaria mellea was most frequently isolated. Typical mycelial fans were observed

Table 4.--Summary of collections from which isolations were attempted in 1948

Isolation Source	Condition of tree		Part of tree	
	Healthy	Diseased	Bole	Roots
1. Symptom free material[1/]	6	5	4	7
2. Lesions in bark[2/]	19	23	9	33
3. Sunken areas in bark	9	4	9	4
4. Lemon-colored bark	3	34	34	3
5. Water soaked bark	1	4	0	5
6. Superficial fungi	4	3	0	7
7. Mycorrhizas	4	7	0	11
8. Stains	10	6	1	15
9. Decays	11	44	4	51
10. Water core	0	7	7	0
Totals	67	137	68	136

1/Material free of conditions listed in 2-10, incl.
2/Excludes isolations attempted from lemon-colored bark beneath lesions which are included in 4.

on all trees excavated in root studies, but routine cultures were not made in every case. The fungus developed in 15 isolations of 7 different sources on the Kaniksu and Clearwater National Forests. It was observed on the Coeur d'Alene, St. Joe, and Kootenai National Forests, but isolations were not made. Comparative cultural studies must be completed before the occurrence of other common root rotting fungi can be reported.

Isolations from stem material have yielded many different organisms, a number of which appear to have been obtained also by Welch.[1/] For example, our isolations apparently include Cryptosporium sp., Atropellis sp., Cucurbidothis sp., Stigmella sp., and Endobotryella sp., all of which he identified, and undoubtedly a number of others he isolated but did not name.

1/Transfers were made of D. S. Welch's stock cultures through the courtesy of the University of Idaho.

It is planned to analyze the source of frequency of occurrence of organisms retained in stock culture. This should augment results of inoculation tests and aid in eliminating harmless organisms, thus leaving those that may possibly have either direct or indirect significance in pole blight. In general, identification will be limited to apparently significant organisms.

Soil Micro-Organisms

Studies of soil micro-organisms were started during the latter part of the 1948 field season. Objectives of the studies were (1) to determine if any of the fungi isolated from diseased and healthy roots are present in the soil and (2) to determine if there are significant differences in the number or variety of fungi in the soil from diseased and healthy stands.

Soil samples were collected during August and September in conjunction with excavations of root systems described in another section of this report. Approximately 4 ounces of soil were collected in powder jars from 6, 12, and 18 inches below the surface. On the Kaniksu National Forest additional soil samples were collected from 24 inches below the surface. The samples were taken to Albuquerque in October and stored at 0°C except for short periods when portions of the samples were being transferred to cultures in the laboratory.

Two types of isolations have been made using Waksman's Soil Fungi Medium in both cases. In the first type, lumps of soil about 0.5 cm. square were planted on the surface of agar in petri dishes, and incubated at room temperature. Duplicate plantings were made for each soil depth. This type of isolation has been repeated once.

In the second type of isolation, tap water dilutions of soil (1:50, 1:500, and 1:5000) were mixed with liquid agar at about 49°C, poured into sterile petri dishes, and incubated at room temperature. (Plate IV.) This type of isolation has been repeated once using 1:250 and 1:2500 instead of the original dilutions.

Tables 5 and 6 summarize the quantitative results of the isolations from soil. No obvious differences between diseased and healthy areas are evident in Table 6. The most noteworthy feature in this table is the low population of fungi at the 18-inch level for both samples from the Kaniksu National Forest. This was probably due to the impervious nature of the soil between 14 and 20 inches. The high count for fungi at the 6-inch level, sample 4 of the Clearwater National Forest, probably has no significance as there was evidence of recent garbage disposal at that location.

Practically all fungi that developed in the plates were transferred to test tubes about 10 days after growth started. Tube cultures will be retained for taxonomic study as time permits. Pending identification, the fungi have been classified according to cultural appearance, as summarized in Table 5, except in the case of easily recognized soil inhabitants such as Penicillium sp., Trichoderma sp., etc. Some isolates resemble fungi that have been recovered from roots of western white pine but further study is required to verify the similarities.

The current results of this phase of the investigation do not properly indicate its importance. Taxonomic studies of isolated fungi need to be completed before the soils from diseased and healthy stands can be compared on the basis of the quantity and quality of their micro-floral content. It is planned to repeat isolations once more using slightly modified techniques to preclude the death of organisms sensitive to temperatures required to keep agar in a liquid form. Additional samples will be collected during the coming field season.

Table 5.--Soil planting. Frequency of occurrence of color groups
No. plates - 4

National Forest	Sample No.	Depth, inches	White[1/]			Tan	Gray	Green[2/]		Others
			1	2	3			1	2	
St. Joe	1	6	3	2	0	2	3	1	4	0
		12	0	2	0	0	0	1	3	0
		18	0	2	1	0	0	0	4	2
			3	6	1	2	3	2	11	2
do.	2	6	1	0	0	0	4	0	0	0
		12	0	2	0	4	2	0	0	0
		18	4	1	1	0	3	0	1	0
			5	3	1	4	9	0	1	0
do.	3	6	3	1	0	2	2	0	4	1
		12	0	2	0	0	0	0	4	0
		18	0	3	1	0	1	0	4	0
			3	6	1	2	3	0	12	1
Clearwater	1	6	1	3	0	2	4	0	1	0
		12	3	2	0	1	3	0	2	0
		18	4	0	0	2	2	0	4	0
			8	5	0	5	9	0	7	0
do.	2	6	4	1	0	0	1	0	0	0
		12	1	3	0	2	3	1	0	0
		18	4	4	0	3	2	1	0	1
			9	8	0	5	6	2	0	1
Kaniksu	1	6	3	4	2	3	0	0	0	0
		12	0	0	0	0	3	1	1	0
		18	4	1	0	1	0	4	0	0
		24	2	1	0	2	3	1	1	0
			9	6	2	6	6	6	2	0
do.	2	6	3	3	0	1	3	1	0	0
		12	4	0	0	2	0	0	0	0
		18	4	4	0	2	0	0	0	0
		24	4	2	0	1	2	0	1	0
			15	9	0	6	5	1	1	0

1/Col. 1 - floccose, Col. 2 - appressed, Col. 3 - submerged.
2/Col. 1 - light in color, Col. 2 - dark in color.

Table 6.--Soil dilutions, Series 2. Counts shown based on 1:250 dilution

National Forest	Sample No.	Soil Depth (ins.)	Thousands of Colonies in Soil per gr.
St. Joe	1	6	18.5
		12	4.5
		18	7.0
do.	2	6	13.0
		12	5.6
		18	0.8
do.	3	6	10.8
		12	3.0
		18	3.8
Clearwater	4	6	65.1
		12	6.5
		18	3.1
do.	5	6	12.8
		12	3.6
		18	1.5
Kaniksu	6	6	15.5
		12	3.8
		18	0.1
		24	1.4
do.	7	6	13.0
		12	2.8
		18	0.5
		24	5.5

Preliminary inoculations

A number of inoculations have been made using some of the organisms that have been isolated from blighted and healthy trees. The first series was made during August and September 1948 in the laboratory at the Priest River Experimental Forest. It involved the inoculation of freshly collected sections of western white pine stems and roots. The other two series were made in the laboratory at Albuquerque, New Mexico. They involved the inoculation of stem sections only.

The material for the first Albuquerque series was collected early in October 1948 in a stand outside the known range of pole blight. The material used for the other Albuquerque series was collected for us by personnel of the Northern Rocky Mountain Forest and Range Experiment Station during January 1949, in a stand within the pole blight area. Clear stems were used in all cases, the branch whorl portions being discarded. Stems varied in diameter from 2 to 4 inches; roots varied from 1/4 to 3/4 of an inch. Sections were freshly trimmed to more or less uniform lengths after they were taken to the laboratories. They were then surface sterilized with a commercial hypochlorite solution, coated with paraffin at the ends, or over the entire surface in the case of roots, to prevent drying, and stored at 5°C until inoculated. Examinations made just prior to inoculation indicated that the sections were in a good state of preservation with succulent green bark on the younger sections, and necrosis associated with drying rarely extending more than 1/4 of an inch from the ends. Appearance of stem sections before inoculation is shown in Plate V, Top.

In the first series of inoculations a variety of methods for introducing the inoculum were tested. Since the results of this series indicated that needle punctures extending to the wood were satisfactory, this method was used almost exclusively in the other series.(Plate V, Center). Punctures were made at least 2 inches from the ends to reduce the chances of end drying merging with any necrotic zones that might be associated with inoculations. Vigorous malt agar cultures of the organism were smeared over the punctures and covered with moist cotton. Sterile agar was smeared over punctures on the opposite face of each section and also covered with moist cotton. None of these checks developed necrotic bark beyond the punctured area. The inoculations and checks were kept in a moist atmosphere for three days, then retained in the relatively dry atmosphere of the laboratory for the duration of observations, approximately 21 days.

Table 7 summarizes the inoculations made on 62 stem sections in the three series. It indicates that inoculations with culture No. 603 (Scopularia sp.) and similar isolates in cultures No. 694, 724, and 763 resulted in necrosis of the inner bark, (Plate V, Bottom) leading in the case of succulent smooth-barked sections to the development of marked depressed zones or "sunken" areas (Plate VI). Of all the other cultures listed only No. 602[1/] can be considered equally suspect on the basis of results of these inoculations.

1/A heterogeneous isolate resembling No. 603 in part, but treated as a distinct culture pending study of the component fungi.

Table 7.--Summary of inoculations made on 62 stem sections

Inoculation (Culture No.)	Number of Inoculations: Total	Positive[1]	Doubtful	Negative	Remarks on Source
602	10	4	5	1	Stem lesion[2] bark
603	7	7	0	0	Dead lateral root
603S	20	18	1	1	Monoconidial
605	5	0	1	4	Dead lateral root
607 -	7	0	0	7	Stem lesion bark
608 -	4	0	0	4	do.
609 -	4	0	1	3	do.
615 -	5	0	0	5	do.
619 -	5	0	0	5	do. wood
628 -	5	0	0	5	do.
659	2	0	0	2	Cankered lateral root
694[3]	4	1	0	3	Root collar
719	5	0	0	5	Stem lesion bark
724[3]	4	2	1	1	Dead lateral root
731	8	1	0	7	Stem lesion bark[4]
739	8	1	0	7	do. [4]
761	4	0	0	4	Inoc. stem section
762	4	0	0	4	do.
763[3]	4	3	0	1	Dead lateral root
764	8	1	2	5	Stem lesion bark[4]

1/As indicated by extensive bark necrosis.
2/Under term lesion are included cankers and sunken areas in bark.
3/Similar to Culture No. 603.
4/Isolated and used for inoculations by Welch. Available to Forest Pathology through cooperation of the University of Idaho.

The introduced organisms were re-isolated without difficulty from both bark and wood of representative positive inoculations at the conclusion of each series. In a few cases other organisms were isolated from positive-appearing inoculations either alone or in conjunction with the organisms originally introduced in culture. It is believed possible that this indicates some naturally occurring fungi either remained viable despite the sodium hypochlorite treatment or invaded the sections sometime during the tests; possibly they were present in the mass isolates used. For example, cultures No. 761 and 762 were isolated from sections inoculated with the mass isolate No. 603. As indicated in Table 7, they have already been tested and found to be incapable of causing any of the typical positive reactions in stem sections. In other cases, especially on sections from the pole-blight area, isolations were also made from sunken areas, bark necrosis and sapstain that developed during the observation period but which did not appear to be associated with inoculations or checks. Isolates from this source will also be tested.

Table 8 summarizes the inoculations of the two Albuquerque series made in needle punctures with culture No. 603 as a mass and as a monoconidial isolate. Other inoculations utilizing different methods for introducing the inoculum of this isolate are in progress. From the table it can be seen that (1) all inoculations were positive, (2) size of necrotic areas was not markedly different in smooth and rough barked sections, in sections incubated at 62°F and 72°F, respectively, or in sections inoculated

Table 8.--Inoculations of stem sections with Organism No. 603

Section No.	Bark	Incubation Temp.[1]	Type of Inoculum	Size of affected area after 21 days: Bark[2] Width	Bark[2] Length	Wood[3] Width	Wood[3] Length
				inches	inches	inches	inches
3	Smooth	62°F	Mass	9/16	1-1/4	-	-
9	do.	do.	do.	1-1/4	4-1/2	-	-
15	do.	do.	do.	1-3/4	5-1/4	-	-
19	Rough	do.	do.	1-1/2	2-1/2		Trace
26	Smooth	do.	do.	1-3/8	2-1/6		do.
33	Rough	72°F	do.	1-5/8	5-3/4	3/8	2
40	Smooth	do.	do.	1-7/8	5-7/8	5/8	2-5/8
25	Rough	62°F	Monoconidial	1-1/4	3-1/4		Trace
32	Smooth	do.	do.	1-7/8	5-1/4	5/8	1-1/4
39	Rough	72°F	do.	2	6	3/16	2-3/8
46	Smooth	do.	do.	3	6-1/4	1.0	6-1/4
52	Smooth	62°F	do.	2	6-1/2	3/4	4.0

1/Incubation period in a humid atmosphere to prevent drying of inoculum lasted 3 days, after which all sections were kept at room temperature and humidity.

2/Sunken areas if present, otherwise necrosis.

3/Characteristic stain due to dark hyphae.

with the mass isolate and the monoconidial isolate. Two disadvantages to the use of rough barked sections not evident from the table are (1) sunken areas rarely developed as indicators of bark necrosis, and (2) normal bark plate formation complicated the necrosis associated with inoculations. Though not apparent in the table, measurements made every fourth day suggested that 72°F may be more favorable to rapid establishment and growth than 62°F.

In the first series, 14 inoculations were also made on root sections using 7 isolates from roots, including 4 of Armillaria mellea. Organism No. 603 was not used. Each isolate was inoculated by needle punctures and by smearing inoculum at the base of a fibrous root. Checks made with sterile agar remained negative. Only three inoculations, all smears at the base of fibrous roots, had caused limited bark necrosis at the end of thirty days. While A. mellea was associated with necrosis in one of these cases, it was not re-isolated. The only isolate recovered was an unidentified Basidiomycete. It is believed that these inconclusive results were due in part to the fact that the inoculations dried out before the fungi were established and to the small sample used. It is planned to repeat tests of this nature and to make additional inoculations of living roots during the coming field season.

Limited tests with conidial suspensions indicate that organism No. 603 readily establishes itself on the bark and cut ends of root sections, but observations were not continued long enough to tell if it can cause the extensive bark necrosis and sapstain associated with it in inoculated stem sections.

Inoculations of stem sections in the laboratory must be considered decidedly preliminary in character. Regardless of the excellent state of preservation of the sections, they were undoubtedly incapable of actively resisting invasion by aggressive fungi. It is possible, however, that the results of inoculations with culture No. 603 indicate that this organism can attack devitalized or dormant trees, and that it should be given priority in large-scale inoculations of living trees during the coming field season.

Limited temperature studies were made using a monoconidial isolate of organism 603 because it was felt that the results might provide some indication as to the best time of year to make inoculations in the field.

Results of the study indicate cardinal temperatures within the following ranges: 0 - 5°C, 15 - 20°C, and 25 - 30°C. Temperatures above 35°C appear to be lethal to the fungus. It is able to grow slowly at 0°C.

Since the fungus is capable of making good growth at relatively low temperatures, e.g. about 7 mm. per day at 11°C, it is possible that the most favorable time for artificial inoculations will prove to be during the dormant season for the host either in the late fall or early spring.

Damage studies

The first of several sample plots planned for the Bear Paw Creek area was established in 1948. This is the 44-acre tract on the Kaniksu National Forest given a commercial thinning in 1939, at which time an "unclassified disease" was noted. (see Gill, L. S. A preliminary report on mortality of western white pine in the Bear Paw Tract of the Kaniksu

National Forest. 4 pp. Typed. Oct. 8, 1948.) Since the disease, now classified as pole blight, has been developing from several well-defined centers but is not yet general throughout the area, it is anticipated that a series of well-distributed plots will provide fairly complete information on the rates of intensification and spread and supplement damage studies based on 100 percent cruises of the tract.

A 1-acre plot was located in one of the early disease centers. It was surveyed by staff compass and chain and tied-in to previously located Forest Service Silvicultural Plots. White paint was used in numbering living trees and in marking dead trees with the symbol "0". All trees 3.6 inches d.b.h. and larger were measured with a diameter tape. Records of individual trees conformed approximately to the data collected on University of Idaho sample plots and included (1) crown class, (2) estimated density and color of foliage in the upper and middle crown, (3) relative size of cone crop (4) retardation in shoot elongation, and (5) extent and location of pitch flow and so-called pole-blight cankers. Items (2) through (5) provided the basis for estimating the degree to which a tree was blighted.

A brief summary of results follow. Although it is obvious that one set of observations on a single plot do not provide the basis for fulfilling the original objective, eleven, or 46 percent of the 24 merchantable trees (11.1 inches d.b.h. and larger) in the residual stand have died since the improvement cutting, and all but 2 of them probably succumbed to pole blight. Ten of the 13 remaining live trees, or 77 percent, were showing signs of pole blight in 1948, and have a maximum life expectancy of 5-6 years according to

general observations of the disease elsewhere. Of the 29 live trees smaller than 11.1 inches d.b.h., only 5, or about 17 percent, appeared to be blighted, although they are believed to be just as old as the merchantable-sized trees. Table 9 shows the relationship found to exist between diameter and mortality.

Five-year measurements for the period 1929-1948 were made on increment cores from the living trees on the plot. All but 2 of the 10 trees estimated to be suffering from pole blight showed a recession in radial growth beginning as early as 1941 in some cases, and as late as 1948 in others. Five trees displayed evidence of release following the 1939 cutting, but in three of them the accelerated growth rate was off-set by a declination in the next 5-year period. It is believed that increment core measurements are not a satisfactory basis for analyzing the effect of pole blight on diameter growth. Inasmuch as some portions of the cambium may be killed or devitalized, while others may remain alive or vigorous and continue to form new tissue at a normal rate, examination of the entire circumference at several heights apparently is desirable before attempting measurements or interpretation.

It is planned to establish additional plots in the Bear Paw Creek Area and in any localities where extensive surveys or cruises require supplemental studies.

Virus tests

During the latter half of July a number of patch grafts were put in on both roots and stems of healthy trees of pole size. This work was done in the areas marked "Patch Graft Plots" (Fig. 1). Scion material from both

Table 9.--Pole blight loss by diameters. 1-acre sample plot in Bear Paw Creek, Kaniksu National Forest

D.B.H. Class	Total No. trees	Dead or declining	
		No.	Percent
4	14	0	0
6	13	3	23
8	19	8	42
10	11	8	72
12	6	4	67
14	9	6	67
16	7	7	100
18	1	1	100
20	1	1	100

healthy and diseased trees was used. An examination of the plots in late September showed that all grafts had failed, the patches for the most part being moldy or dried out. Experience with other species of pine indicates that success cannot be expected unless grafting is done at least a month earlier when the bark "slips" easily. This work was undertaken primarily as a means of becoming familiar with the technique and little hope for success was entertained at the time it was done.

Recommendations for Further Work

It is felt that the first step toward a full understanding of pole blight is to assemble more basic information relative to the ecology including normal succession of western white pine stands. It is believed that important strides to that end could be made with relatively little effort by studies of age-spread in overmature white pine stands throughout its range. The primary objective of such a study would be to determine to what extent in the past dense, even-aged, fast growing stands have exceeded the 120-year mark without suffering severe losses. If such a study shows that losses have been heavy during 40-80-year age periods in mature stands it could be inferred that a condition similar to pole blight is in a sense normal. On the other hand, if the studies show nothing of the sort it can be postulated at least that the disease is relatively new and possibly introduced. Such information would have an important bearing in deciding the course of further investigations and control programs. If we are dealing with an introduced disease the situation is indeed grave. If the condition is to be regarded as a more or less natural one it nevertheless presents a

challenge to discover the conditions or factors which bring about the losses and through such knowledge develop methods for reducing them through proper silviculture and management. It is doubtful if the Division separately could conduct such an ecological study without sacrificing work of a strictly pathological nature, but we should be very glad to do so in cooperation with other agencies.

There is an urgent need for more reliable information on the extent, spread, and intensification of the disease. It is important to know within reasonable limits of accuracy how far it has gone, where it is going, and what the annual toll amounts to. Those are simple economic questions that must be answered before any disease problem can be evaluated. Such information is also essential for the study of any new plant disease in that it may help determine whether or not the trouble is of an infectious nature. To this end the Division should assist in a training program for pole blight scouts who will conduct a survey under the auspicies of the Forest Service. It is also to be hoped that the training can be extended to National Forest Personnel and to foresters and others in private employ. The Division should have at least one man on its staff whose principal duty will be to give technical help in conjunction with the survey crews and others who might report suspected new areas. By acting as a clearing house for such information this man should be of considerable help in planning the course of strictly investigative work, especially in conjunction with damage studies.

Pathological work should continue to emphasize research that will reveal the cause of the disease. Tests to determine whether or not a virus is involved should be started as soon as possible in the spring of 1949. Inoculations with suspected fungi should be made at monthly intervals (if not more often) throughout the year. Isolations from soil and pine tissue should be continued and considerable attention given to the identification of the organisms on hand and to be obtained. Damage study plots should be established wherever suitable circumstances dictate. Attention should be given to nutrient deficiencies and a thorough study of soil in relation to the disease should be made. This work would be done largely by the University of Idaho and the Division of Forest Pathology.

Pending the development of information relative to the cause and behavior of the disease, attention should be given to the problem of salvage and if possible to control by empirical methods. The success of the latter should influence to some degree the ultimate policy with respect to salvage.

Prepared at: Albuquerque, N. Mex.
May 9, 1949, by

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PLATE I

Illustrating Root Study Technique

Top: Root system washed out. St. Joe National Forest

Bottom: Dissected stump following analysis of root system. The large root issuing from the center and swinging to the right is the main tap root which is serving as a major lateral. One of several lateral tap roots can be seen at the lower right of the photograph.-- Kaniksu National Forest.

PLATE II

Common abnormalities found on roots

Top: Accumulation of resin in soil adjacent to root lesions. Those in the photograph are at the base of a stump but similar conditions can prevail anywhere in the root system.--St. Joe National Forest.

Bottom: (left) A common type of mycorrhiza found on western white pine roots as it appears when first excavated. Natural size. --Kaniksu National Forest.

Bottom: (right) The same mycorrhiza as shown in bottom left after washing away the soil. (X4) -- Kaniksu National Forest.

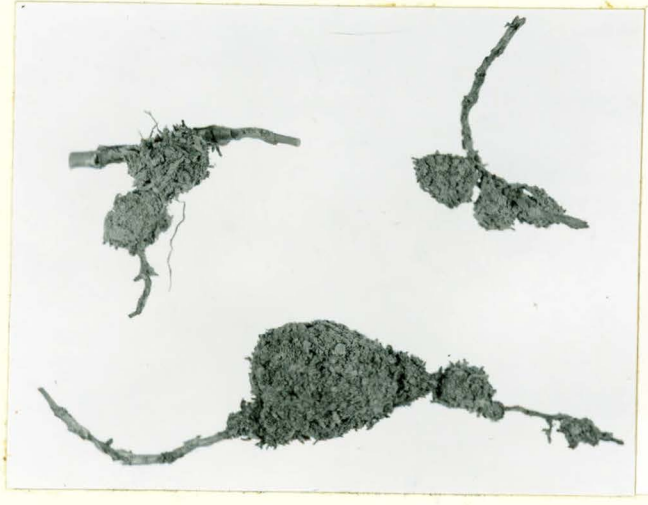


PLATE III

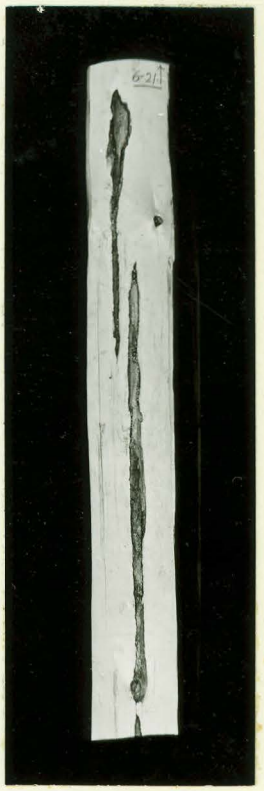
Natural stem lesions

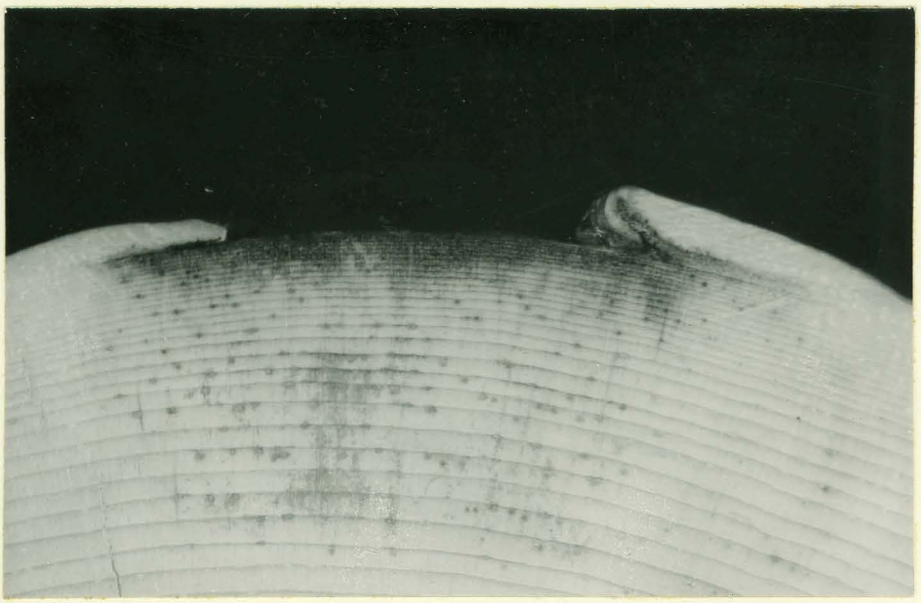
Top left: Elongate cankers occurring at 16-20 feet above the stump. These cankers are frequently found on the main stem in the mid-crown of blighted trees.(See Fig. 3)

Top right: Cross section through canker illustrated above showing efforts to heal at edges. Note the series of narrow annual rings. The dark area and scattered dark spots are caused by resin which has infiltrated into the wood. (X 2.5). --Kaniksu National Forest. (See Fig. 3)

Bottom left: Sunken bark patch near the top of a diseased tree. This condition is common in blighted trees but has also been found in planted stock about 15 years old.

Bottom right: Same as bottom left with outer bark peeled to show necrotic tissue in sunken area.





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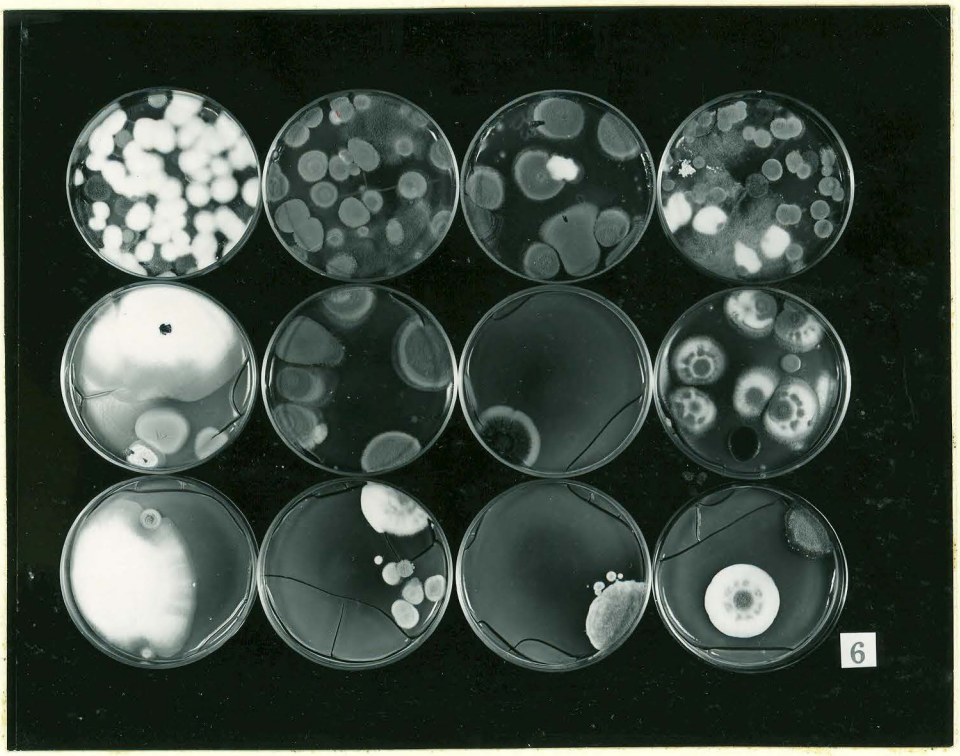

PLATE IV

Fungi growing on Waksman's Soil Fungi Medium three weeks after inoculation with tap water dilutions of soil. Petri dishes containing samples of soil from 6, 12, 18, and 24 inches below the surface are arranged in vertical rows from left to right. Dilutions of 1:50, 1:500, and 1:5000 are arranged in horizontal rows from top to bottom. Samples for this series were taken from soil adjacent to the roots of a diseased western white pine in the Bear Paw Creek Drainage, Kaniksu National Forest.

PLATE V

Artificial Stem Lesions

Top: Series of western white pine stem bolts before inoculation. The ends of these pieces were dipped in "Purex" 2 percent solution and covered with warm paraffin on the day they were collected. They were held in a refrigerator at about 5°C for several weeks before inoculation.

Center: Same as top 11 days after inoculation. The needle punctures indicate the extent of wounding for inoculation purposes.

Bottom: Same as top 25 days after inoculation with outer bark removed to show necrosis. Organism No. 603 on stem No. 15 produced a fusiform necrotic area. In the case of the other 5 sections necrosis was limited to the immediate vicinity of the punctures. Unaffected bark showed no visible signs of deterioration. (See Plate VI.)

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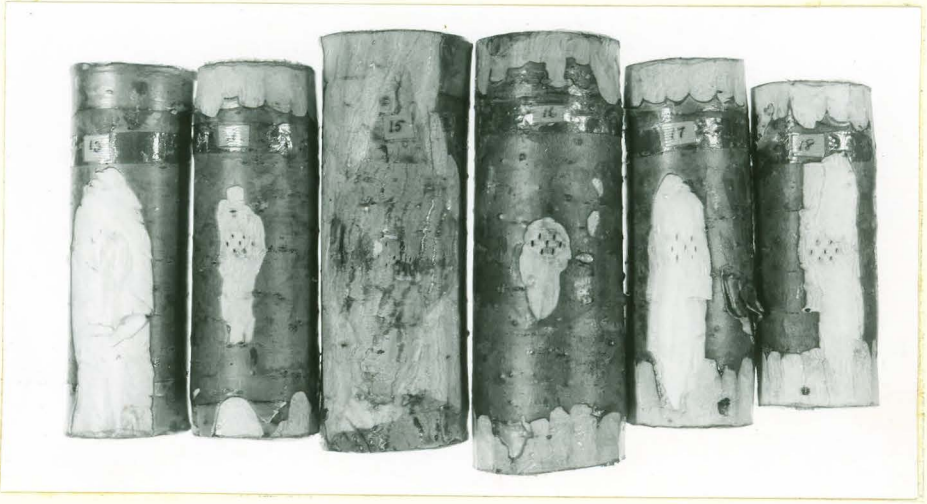
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PLATE VI

Artificial Stem Lesions with Organism No. 603

Top left: Inoculation No. 3 showing sunken bark after 13 days.

Top right: Inoculation No. 15 (See Plate V) after 13 days.

Bottom left: Inoculation No. 9 after 21 days.

Bottom right: Same as bottom left after 24 days with outer bark removed from lower half of sunken area to show fusiform necrotic tissue beneath.